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CISLUNAR LEXICON

Cislunar Position, Navigation and Timing
Recommended Terms for Cislunar Operations

by

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In the following, words or phrases that are italicized are defined as part of this list. IAU refers to the International Astronomical Union, the international organization of astronomers that, among other things, establishes conventions, definitions, and standards for astronomical work. The IAU often coordinates such standards, when applicable, with the International Union of Geodesy and Geophysics (IUGG).

Apoapsis: the point at which an object in orbit is furthest from the body it orbits. This point is called *apolune* for lunar orbits and *apogee* for Earth orbits.

Astronomical Unit (au): a unit of length defined as 149,597,870,700 m. It is approximately equal to the mean distance from the Sun to Earth's orbit.

Augmented Forward Signal (AFS): a standardized navigation signal for proximity broadcasting designed for lunar missions and is extensible to other bodies. A key component of the *LunaNet* network, the **AFS** enables interoperability between different service providers and intends to be broadcast by satellites orbiting the Moon, to provide precise positioning, navigation, and timing data, alert data, and low-rate communications data to users in the identified service volume at the Moon.

Atmosphere: the layer of gases surrounding and gravitationally bound to a celestial body.

Barycenter: the center of mass of a system of bodies (e.g. the center of mass of the solar system or the Earth-Moon system).

Barycentric Celestial Reference System (BCRS): a system of barycentric space-time coordinates for the solar system within the framework of *general relativity* with geometric origin at the solar barycenter. The BCRS is specified by IAU Resolution B1.3 and is oriented to the axes of the *International Celestial Reference System (ICRS)*.

Barycentric Coordinate Time (TCB): the coordinate time of the *Barycentric Celestial Reference System (BCRS)*, expressed in units of *SI seconds* within that system. TCB is related to *Geocentric Coordinate Time (TCG)* and *Terrestrial Time (TT*) by relativistic transformations which include a secular term. When compared to TT, it has a mean difference of about 0.5 s/yr.

Barycentric Dynamical Time (TDB): the coordinate time of the *Barycentric Celestial Reference System (BCRS)* with a rate offset from *Barycentric Coordinate Time (TCB),* so that its mean rate is approximately equal to *Terrestrial Time (TT)* for several millennia around J2000.0. This is the coordinate time scale for the JPL solar system ephemerides.

Cartography: the art and science of creating maps. **Cartographic** refers to anything related to maps or mapmaking.

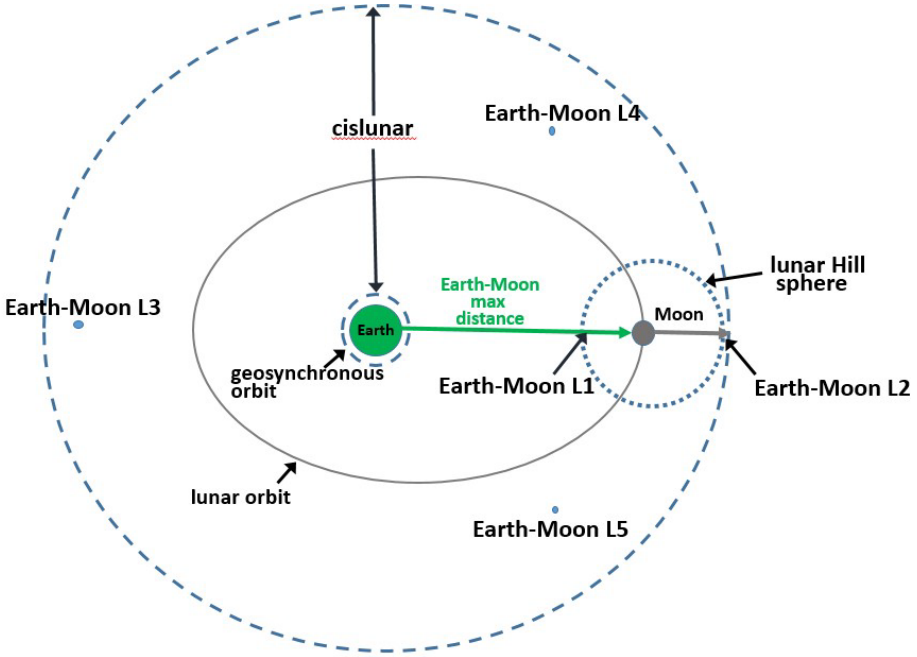
Celestial body: a single, tightly bound, contiguous natural entity located in space (e.g. asteroids, comets, planets, Earth, natural satellites, and stars). Their motions can easily be

modeled and predicted using the principles of celestial mechanics.

Celestial object: any less cohesively bound entity located in space, which may consist of multiple bodies or substructures (e.g. spacecraft).

Cislunar: located in the spherical volume of space whose radial distance extends from Earth's center just beyond the *Earth-Moon L2 Lagrange Point*, excluding the spherical volume within Earth's *geosynchronous* orbit.

Cislunar region (not to scale)



Coordinate frame: The set of axes from which the position of a point can be determined. The **coordinate frame** establishes the origin, orientation, and scale for the units of measurement used in the *reference system*.

Coordinate system: a method of specifying the position of a point in space relative to a coordinate frame.

Coordinated Lunar Time (LTC): a yet-to-be defined time scale that serves as a realization of lunar time, traceable to *UTC*.

Coordinated Universal Time (UTC): a time scale based on the SI second on the Earth's rotating *geoid*, formed from the average of hundreds of atomic clocks at metrology laboratories worldwide. The frequency of the time scale is referenced to the SI second at the *geiod* using a select number of primary and secondary frequency standards. UTC is maintained within 0.9 s of *Universal Time (UT1)* by inserting or removing a second, when necessary (a "leap second" adjustment). UTC is the basis for the worldwide system of civil time.

Coordinated Universal Time USNO (UTC(USNO)): the realization of UTC as maintained by the U. S. Naval Observatory. It is the authoritative time for the DoD and is the reference to which the

Global Positioning System (GPS) time is steered (modulo 1 s).

Digital Elevation Model (DEM): a digital representation of ground/surface topography or terrain. DEMs can be bare-earth models, which includes only natural terrain but excludes vegetation, buildings, and other structures, or surface models, which include both natural terrain and surface features such as vegetation and buildings. DEMs are used for precise geopositioning, extracting terrain parameters, spatial modeling, and visualization.

Distant retrograde orbit (DRO): an *orbit* around a moon that is stable owing to its interactions with the L1 and L2 *Lagrange points* of a planet-moon system. As seen from the surface of the *primary body*, a **DRO** looks like a large elongated *retrograde orbit* around the *secondary body*. The employment of such a long-term stable *orbit* minimizes the use of station-keeping propellant.

Earth's atmosphere: the layer of gases surrounding and gravitationally bound to the Earth. The upper boundary of the Earth's atmosphere is conventionally set at an altitude of 100 km (the *Kármán line*), though rarified gases are also present above that line.

Earth's ionosphere: the region of space surrounding Earth, containing rarified gases whose atoms are ionized (electrically charged). The ionosphere extends from an altitude of about 50 km out to about 1,000 km.

Earth's magnetosphere: the region of space surrounding Earth, in which particles are charged by Earth's magnetic field. It extends from about 1,000 km to about 65,000 km on Earth's dayside, and to about 6,300,000 km on the night side.

Ecliptic: 1) The mean plane of the orbit of the Earth-Moon *barycenter* around the solar system *barycenter.* 2) The great circle on the celestial sphere that represents the extension of that plane to infinity. 3) The yearly path of the Sun in the sky as seen from Earth.

Elliptical Lunar Frozen Orbit (ELFO): a frozen orbit about the Moon, with a critical inclination that sets *periapsis* and *eccentricity* rates to zero. ELFO have an *eccentricity* value of at least 0.1., although ELFO typically have high *eccentricities* in the 0.6 or 0.7 range. These orbits provide extended line-of-sight to the lunar polar regions.

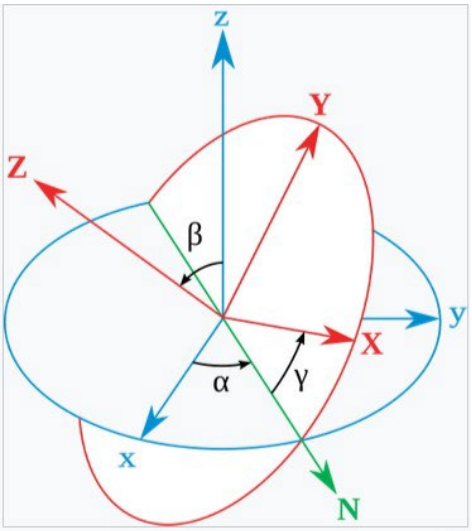
Ephemeris: a time-ordered sequence of the positions, velocities and, possibly, orientation.

Epoch: an arbitrary fixed instant of time or date used as a chronological reference (e.g. for calendars, reference systems, star catalogs, or orbital motions.)

Equinox: two points on the *celestial sphere* at which the *ecliptic* intersects the celestial equator, or the dates on which the Sun appears to cross those points. At these points, the durations of sunlight and darkness are equal.

Euler angles: three angles used to describe the orientation of a rigid body/coordinate frame with respect to a fixed coordinate frame, as in the figure below.

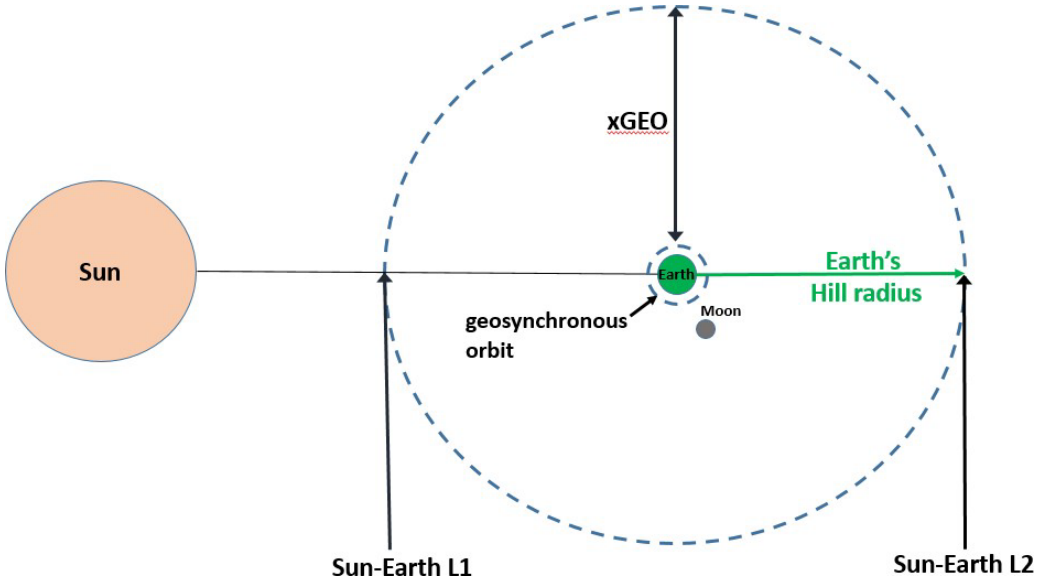
The Euler angles. Borrowed from https://en.wikipedia.org/wiki/Euler_angles



Classic Euler angles geometrical definition.
Fixed coordinate system (x, y, z)
Rotated coordinate system (X, Y, Z)
Line of nodes (N)

Exclusion zone: the area where a sensor cannot track an object that is in close proximity to or occulted by a celestial body. This area will change with the location of the sensor, the size of the object and the celestial body, the intensity of radiation coming from the celestial body, as well as the frequency band of the observation (e.g. Earth, lunar or solar exclusion zone).

Extended geosynchronous (xGEO): located in the spherical volume of space from Earth *geosynchronous* orbit to the end of Earth's gravitational dominance over that of the Sun (the Earth-Sun L2 *Lagrange Point*), approximately 1,470,000 km (well beyond the lunar orbit).



Far Side of the Moon: the lunar hemisphere that always faces away from Earth. Most of the Far Side (about 82%) can never be observed directly from Earth due to the Moon's rotation being synchronous (on average) with the Moon's orbital motion around Earth.

Frozen orbit: an *orbit* of a *secondary* about the *primary* (usually, of an artificial satellite about Earth or the Moon), in which natural drifting due to the *primary's* shape is minimized by careful selection of the orbital parameters (the *orbit's* size and orientation). The employment of such a long-term stable *orbit* minimizes the use of station-keeping propellant to compensate for gravitational forces.

Gateway: a planned small, multi-purpose lunar space station supporting lunar surface missions, science in lunar orbit, and human exploration further into the cosmos. To be built and operated by NASA, in collaboration with commercial and international partners. Scheduled to be launched into a *near- rectilinear halo orbit*.

Geodetic: relating to or determined by *geodesy*.

Geodesy: the scientific study of the size shape, gravity, and spatial orientation of a celestial body and the variation of those features over time

General relativity (GR): a theory describing the relationship between space and time in the presence of gravity. GR is required when precise motion and timing are needed.

Geocenter: the center of mass of the Earth, including *atmospheres* and oceans.

Geocentric Celestial Reference System (GCRS): a system of space-time coordinates within the framework of *general relativity*, with origin at the *geocenter*. The GCRS is specified by the IAU 2000 Resolution B1.3. The spatial orientation of the GCRS is derived from that of the *BCRS*. The transformation between *BCRS* and GCRS spatial coordinates contains no rotation component, so that the GCRS is kinematically non-rotating with respect to *BCRS*.

Geocentric Coordinate Time (TCG): the coordinate time of the Geo*centric Celestial Reference System (GCRS)*, consistent with the *SI second*. When compared to TT, it has a rate difference of about 0.02 s/yr. The rate difference between TT and TCG is named L_G and is provided on page K6 of *The Astronomical Almanac*.

Geoid: a gravity equipotential surface that provides a reference which is tied to the physical characteristics of a *celestial body*. A geoid provides a physics-based reference surface for applications including satellite altimetry, inertial navigation, satellite-based PNT, geodetic survey levelling, and relativistic timekeeping (e.g. for the Earth this is approximately mean sea level).

Geosynchronous orbit: a *prograde orbit* about Earth with a mean geocentric distance of 42,164 km. The orbital period is one *sidereal day*, approximately 23 hours 56 minutes 4 seconds. A geosynchronous body returns to the same point on the sky at the same time each *sidereal day*. (See *Geostationary Orbit*.)

Geostationary orbit: a circular *geosynchronous orbit* in the plane of the equator. An object in such an orbit appears to be motionless above a point on Earth.

Global Navigation Satellite System (GNSS): a satellite constellation designed to provide positioning, navigation, and timing services to users globally. GNSS user equipment uses satellite signals to determine the location of a ground- or space-based receiver by trilateration.

Halo orbit: one member of a family of periodic three-dimensional orbits associated with the L1, L2 or L3 *Lagrange points* in a *three-body system*.

Hill radius: the radius of the *Hill sphere* around a *celestial body*.

Hill sphere: in the *two-body problem*, the spherical region of space around the *secondary body*, in which the *secondary body's* gravitational influence dominates. The **Hill sphere's** radius is the same as the distance from the *secondary* to the L1 and L2 *Lagrange points*. Within the Sun-Earth *two-body problem*, the radius of the Earth's **Hill sphere** is about 1,470,000 km, which is about 3.8 times greater than the Earth-Moon distance. Within the Earth-Moon *two-body problem*, the lunar **Hill sphere** radius is about 58,100 km.

International Celestial Reference Frame (ICRF): A set of extragalactic *celestial objects* whose adopted positions and uncertainties realize the *International Celestial Reference System (ICRS)* axes and give the uncertainties of those axes.

International Celestial Reference System (ICRS): A time-independent, kinematically non-rotating ("space fixed") spatial coordinate system centered at the solar system barycenter, recommended by the International Astronomical Union in 1997. The directions of its axes are defined by the adopted celestial coordinates of several thousand extragalactic objects comprising the International *Celestial Reference Frame (ICRF)*. The ICRS/ICRF provides the spatial orientation of the *Barycentric Celestial Reference System (BCRS)*.

International Lunar Reference System (ILuRS): a yet-to-be defined global "body-fixed" spatial reference system co-moving and co-rotating with the Moon. This is a theoretical concept, comprising requirements on practical reference frames suitable for use with measurements on or near the Moon's surface.

International Lunar Reference Frame (ILuRF): a realization of the *ILRS* through the realization of its origin and orientation axes. This realization is implemented by a set of physical points on the Moon's surface, with precisely determined coordinates in a specific coordinate system.

International Terrestrial Reference System (ITRS): a global "body-fixed" reference system co-moving and co-rotating with the Earth, suitable for use with measurements on or near the Earth's surface. The ITRS origin resides at the *geocenter*, spatial scale is the meter, and time scale is SI seconds. The requirements of the ITRS are governed by international agreements and conventions.

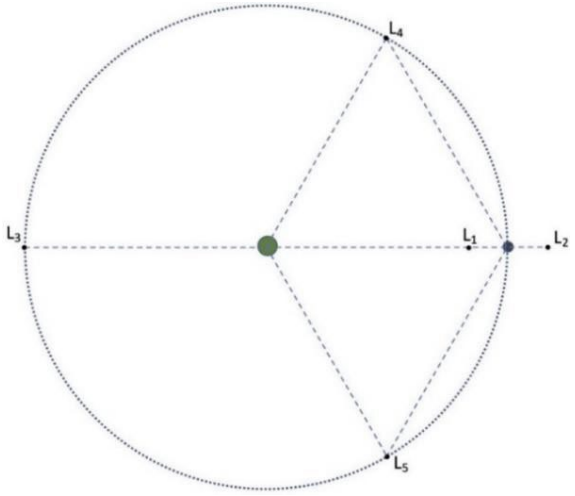
International Terrestrial Reference Frame (ITRF): a realization of the *ITRS* through the realization of its origin, orientation axes, and time and distance scales. This realization is implemented by a set of physical points on the Earth's surface, with precisely determined coordinates and velocities in a specific coordinate system at a particular *epoch*. The ITRF is

maintained by the International Earth Rotation Service (IERS).

(Signal) Jamming: the act of either intentionally or unintentionally interfering with an electromagnetic signal such that it may not be collected by its intended receiver.

Kármán line: a conventional upper boundary of the *Earth's atmosphere*, approximately the altitude beyond which an aircraft has no significant lift. Defined by the Federation aéronautique international (FAI) to be 100 km above mean sea level.

Lagrange points: the set of five points in space at which the gravitational and centripetal forces from two large bodies (such as the Moon and the Earth) approximately cancel, leaving an object at a Lagrange point approximately stationary.



Lagrange Points

L-band: a part of the microwave band of the electromagnetic radiation spectrum covering frequencies from 1 to 2 GHz, as designated by the Institute of Electrical and Electronics Engineers (IEEE). Has a broad application in mobile devices and telecommunications.

Libration: The physical (real) or optical (apparent) oscillations in the rotation of a *celestial body*, or the positional oscillations of an orbiting *celestial body* around a reference point moving in a similar *orbit*.

Libration, physical: real periodic variations in the orientation of a *celestial body* relative to fixed stars, both forced (due to external torques) and unforced.

Libration, optical: apparent periodic changes in the orientation of a *celestial body* as seen from a specific reference point (e.g. the Moon as seen by an observer on Earth) due to periodic changes in the viewing geometry. For the Moon, these variations occur over the course of its orbital period and, to a lesser extent, over the course of a day. For the Moon, the **optical librations** are much larger than the *physical librations*.

Libration, orbital: the positional oscillations of the third body in the *restricted three-body problem* about a moving reference point (often the L4 or L5 *Lagrange points*) with the same average orbital period.

Low Earth Orbit (LEO): an orbit around Earth with a period of 128 minutes or less. This restricts the maximum altitude of a **LEO** to values below 2000 km.

Low Lunar Orbit (**LLO**): an *orbit* about the Moon, located below 100 km mean altitude, and can be considered unstable due to the peculiarities of the lunar gravitational field. Some **LLOs**, known as 'frozen' **LLOs**, are inclined at certain critical angles (27°, 50°, 76°, and 86°) to the lunar equator and can remain stable indefinitely depending on the argument of periapsis and the eccentricity.

LunaNet: a "Lunar Internet" and *GNSS* for *cislunar* spacecraft and installations. The flexible and extensible infrastructure will offer networking and, specifically, will be able to store-and-forward data to provide a data/disruption tolerant network. It will also provide positioning, navigation, and timing services, both for *cislunar* orbit determination and navigation on the surface of the Moon.

Lunar Celestial Reference System (LCRS): a system of space-time coordinates within the framework of *general relativity* with origin at the center of mass of the Moon. The LCRS parameters have the same form as that of the *Geocentric Celestial Reference System (GCRS)* specified by the IAU 2000 Resolution B1.3, with parameter values related to the Moon replacing those related to Earth. The transformation between *Barycentric Celestial Reference System BCRS* and LCRS spatial coordinates contains no rotation component, so that the LCRS is kinematically non-rotating with respect to *BCRS*. The spatial orientation of the LCRS is derived from that of the *BCRS*. Adopted by the IAU in August 2024.

Lunar Coordinate Time (TCL): the coordinate time scale of the *Lunar Celestial Reference System*, consistent with *SI seconds* within that system. Analogous to *TCG*. Adopted by the IAU in August 2024.

Lunar day (sidereal): time for the Moon to complete one rotation with respect to the fixed stars, approximately 27.32 solar Earth days. Also see *sidereal month*.

Lunar day (synodic): time for the Moon to complete one rotation with respect to the Sun. See s*ynodic month*.

Lunar daytime: the time span during which the Sun's apparent disk, or any fraction thereof, is above the local horizontal plane at a given point on the lunar surface.

Lunar highlands: the lighter areas of the Moon. They appear light to the naked eye since they are more reflective. Geologically they are older than *lunar maria* and consequently more cratered.

Lunar Laser Ranging (LLR): the technique of emitting extremely short laser pulses from the Earth to retroreflectors on the lunar surface for the purpose of measuring distance by measuring the round-trip time of the laser pulse. **LLR** is the current basis for both deriving a lunar *ephemeris* and a *lunar reference frame.*

Lunar maria (/ˈmɑːriə/; singular: **mare** /ˈmɑːreɪ/)**:** the large, dark, basaltic plains on the Moon. They appear dark to the naked eye because they are less reflective than the rest of the lunar surface due to their chemical composition. **Maria** cover about 16% of the lunar surface, mainly on the near side of the Moon.

Lunar Month (Lunation): the *synodic* month; the average time it takes for the Moon to complete one cycle of phases as viewed from the Earth. It is the average time between the instants when the ecliptic longitude of the Moon equals that of the Sun as viewed from the *geocenter*. The average duration of a lunar month is 29 (Earth) days, 12 hours, 44 minutes, and 2.8 seconds (or 29.530589 days), although the durations of individual **lunations** vary.

Lunar night: the time span during which no part of the Sun's apparent disk is above the local horizontal plane at a given point on the lunar surface.

Lunar Position, Navigation, and Timing Services (Lunar PNT): Services to be provided by *LunaNet* and other service providers for the purposes of enabling a user position and velocity determination, and time synchronization and dissemination.

Lunar Reference Frame (LRF): an ensemble of control points on the Moon's surface with defined positions at a defined *epoch* used to realize a *Lunar Reference System (LRS)*. The current reference frame is realized through the locations of the five sets of retroreflectors. Proposed to be called the International Lunar Reference Frame (ILuRF)

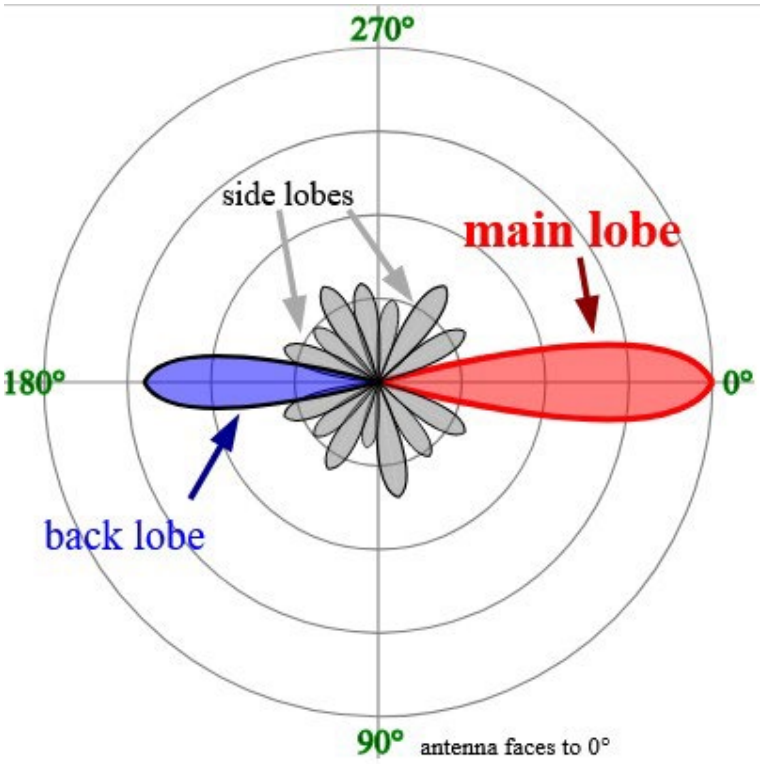
Lunar Reference System (LRS): the coordinate system and environmental models used for mapping the Moon. Proposed to be called the International Lunar Reference System (ILuRS)

Lunar Time (TL): a proposed coordinate time scale that will be based on a standardized gravitational potential on the lunar *geoid*, analogous to the *TT time* scale for Earth.

Lunar Year: a period of 12 lunar months *(lunations*). Its duration is 354 days, 8 hours, 48 minutes, 34 seconds (or 354.367068 days).

LunaNet Reference Time (LRT): common timescale among *LunaNet* Service Providers (LNSP) for interoperability.

Main Lobe: the maximal-intensity lobe (global maximum over all directions) either of the power radiated by a transmitting antenna or of the sensitivity of a receiving antenna. For a directional transmitter (receiver) intended to emit radio waves in (to register radio waves from) a prescribed direction, the lobe in that direction is designated to have a larger emitted power density (a higher sensitivity) than in the other directions.



Lobes of a transmitter or receiver. Borrowed from https://en.wikipedia.org/wiki/Sidelobes

Mean Earth/Mean Rotation (ME) Frame: a lunar *coordinate frame* centered on the center of mass of the Moon whose z-axis aligns with the apparent mean rotational axis and the x-axis aligns with the mean apparent direction to the center of the Earth. NASA has standardized a *reference frame,* DE421 ME, in this *coordinate frame* to serve as the basis for cartographic purposes. Sometimes called Mean Earth-Mean Pole or Mean Earth/Polar Axis.

Meridian: the plane that passes through a given location on the surface of a *celestial body* and its axis of rotation; or a line of constant longitude. A meridian projected onto the sky is a great circle running between the celestial poles through the local *zenith*.

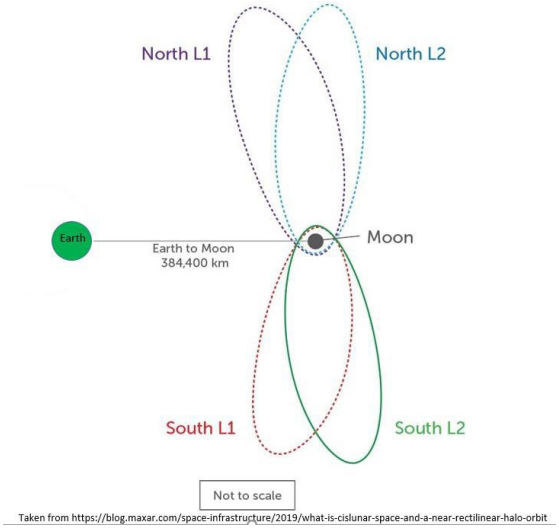
Moon-related adjectives: cynthian, lunar, selenian, selenodetic, and **selenographic:** The adjective **lunar** is used. The term **selenographic** has been used only in application to coordinate systems and axes on the Moon's surface. The term **selenodetic** has been used in applications studying and mapping the Moon's size, shape, surface topography, gravitational and magnetic fields, and tidal response. The adjectives **selenian** and **cynthian** are not recommended for use in scientific or legal texts.

Nadir: a plumb line that extends down to the central gravitational point. The opposite direction of the *zenith*.

Near-Earth Object (NEO): a celestial object in the volume of space between 0.983 au to 1.3 au (147,000,000 km to 195,000,000 km) from the Sun.

Near Side of the Moon: the lunar hemisphere that always faces Earth. Most of the Near Side (about 82%) can always be observed directly from the Earth due to the Moon's rotation being synchronous (on average) with the Moon's orbital motion around Earth.

Near-Rectilinear Halo Orbit (NRHO): a special case of a lunar, highly elliptical *halo orbit* In the Earth-Moon system, the L1 and L2 **NRHOs** are characterized by fast and close passage over one of the lunar poles, the passage over the opposite pole being slower and more distant. A vehicle in an NRHO is always in view of Earth.



Near-Rectilinear Halo Orbits

One-way time transfer (OWTT): a method of communicating time from a source to a receiver that does not require signal transmission from the receiver. Propagation of the time signal through the intervening medium introduces a delay that can only be accounted for with additional information, such as the distance between the two stations. This information can be provided on the transmitted timing signal.

Orbit: the path followed by a *celestial object*, as a function of time. Often used interchangeably with *trajectory*, the term **orbit** is associated with *celestial object* while *trajectory* is more general (e.g. a bullet has a *trajectory*, while a planet has an orbit.)

(Keplerian) Orbital Elements: six specific parameters used to describe the spatial position of a satellite relative to the body or defined point it is orbiting

Orientation Parameters (OPs): a set of any three numbers (usually, the Euler angles) defining the attitude of a body in space, relative to some fiducial orientation.

Periapsis: The point at which an object in orbit is nearest to the body it orbits. This point is called perilune for lunar orbits and perigee for Earth orbits.

Permanently Shadowed Region (PSR): an area on a *celestial body's* surface which never receives direct sunlight. A typical **PSR** is located at the bottom of a crater so deep and steep that

no sunlight penetrates it.

Phases: the cyclically recurring apparent degree of illumination of a body: full (100%); gibbous (50% – 100%); quarter (50%); crescent (0% - 50%); new (0%).

Primary body (**Primary**): usually, the more massive body in a multi-body problem.

Principal Axes (PA) Frame: a *coordinate frame* with its origin at the center of mass of the body, and whose axes are aligned with the body's *principal moments of inertia*. It is used for physical studies of the Moon and given in modern lunar orientation *ephemerides*. For lunar applications, a rotation matrix specific to a given *ephemeris* is required to transform coordinates from a *PA Frame* to a *mean Earth/mean rotation (ME) reference frame.*

Principal moments of inertia Lunar Coordinate System: see *Principal Axes (PA) Frame.*

Prograde motion (direct motion), in the solar system: orbital or rotational motion of a *celestial body* in the same direction as its *primary* is rotating. The orbits around the Sun of all planets and most other objects are prograde. Most planetary rotations are also prograde. The prograde motion of a *satellite* is defined with respect to its host planet. Most natural satellites in the solar system describe prograde orbits about their planets.

Proper time: the time registered by a clock at rest with respect to an observer.

Regional Navigation Satellite System (RNSS): a satellite constellation designed to provide positioning, navigation, and timing services to users in a specific region, typically as an augmentation to *GNSS* constellations.

Reference frame: a catalogue of adopted coordinates of reference points that serves to define, or realize, a particular *coordinate frame*. A **reference frame** specifies a set of identifiable fiducial points along with their coordinates (and velocities, if relevant) at a particular *epoch*.

Reference system: the totality of specifications, models, and constants required to uniquely identify spatial-temporal points. At minimum, a **reference system** includes defined units, a *coordinate frame*, a *coordinate system*, and a *reference frame* to realize the system. Types of **reference systems** can include “body-fixed” **reference systems** which rotate with the figure of the *celestial body* or inertial which are time-independent, kinematically non-rotating “space-fixed” **reference systems** ideal for positioning applications for objects in space.

Resident Space Object (RSO): a *celestial object* that *orbits* a *celestial body*. The term is most often used to reference artificial *celestial objects* that are Earth-orbiting.

Restricted three-body problem: a *three-body problem* where the mass of one body is assumed to be negligible compared to the masses of two other bodies. The dynamics of the two more massive bodies is not influenced by the least massive body and is reduced to the *two-body problem*. The dynamics of the least massive body is determined by the gravitational interaction with the two more massive ones.

Retrograde motion: the orbital or rotational motion of a *celestial object* in the direction opposite to the rotation of its primary. (e.g. Venus orbits in the prograde direction but rotates in the retrograde direction.)

Satellite: the usual name for a *secondary body* or object orbiting a body or object.

S-band: part of the microwave band of the electromagnetic radiation spectrum, covering frequencies from 2 to 4 GHz, as designated by the Institute of Electrical and Electronics Engineers (IEEE). It has a broad application in mobile devices, Wi-Fi networks, and airport radars. It is also used to communicate with spacecraft and for some *RNSS/GNSS*.

Secondary body (**Secondary**)**:** usually, the less massive body in the *two-body problem*. The designation of a secondary is normally dropped if the masses of the bodies are similar or co-orbiting.

Shielded Zone of the Moon (SZM): a naturally radio-quiet zone comprising an area of the Moon's surface and an adjacent volume of space originating from within 100 000 km of Earth's center that are shielded from radio emissions <2GHz, as resolved by the International Telecommunication Union (ITU). In addition to Earth-based radio emissions, the SZM is also isolated from potential interference emanating from the satellites orbiting the Earth.

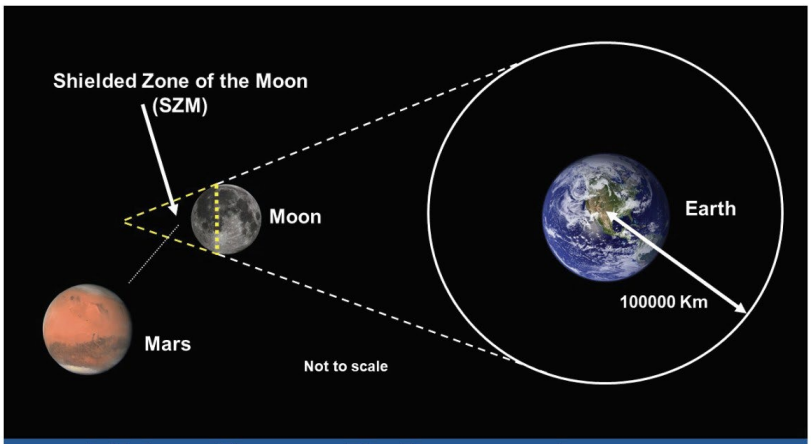


FIGURE 1 Shielded Zone of the Moon as defined by ITU (not at scale).

Borrowed from https://insidegnss.com/protecting-ra-on-the-shielded-side-of-the-moon/

SI second: the unit of time of the International System of Units (Système International d'Unités), which is the time for 9,192,631,770 cycles of the radiation corresponding the ground state hyperfine transition of Cesium 133.

Side Lobe: a lobe (local maximum) of the far-field radiated-power pattern of a transmitting antenna or other radiation source, which is not the main lobe.

Sidereal Earth day: the period between two successive transits of the *equinox* across a given meridian on Earth. The mean sidereal day is 23 hours, 56 minutes, and 4.091 seconds

Sidereal month, also referred to as **Lunar day (sidereal):** the time required for the Moon to

rotate once, about its axis, relative to the cosmic background. Its duration is approximately 27.32 solar Earth days.

Solar Earth day, apparent also referred to as **apparent Solar day,** or **apparent synodic period:** the time required for Earth to rotate once, about its axis, relative to the Sun. It is the time between two consecutive passages of the Sun over the same meridian. The duration of an apparent solar day changes over the course of the year due to the eccentricity of Earth's orbit around the Sun, and Earth's obliquity (the tilt of Earth's rotation axis relative to the normal to its orbit).

Solar Earth day, mean also referred to as **mean Solar day,** or **mean synodic period:** the mean time required for Earth to rotate once, about its axis, relative to the Sun. It is the average time between two consecutive passages of the Sun over the same meridian.

Special relativity (SR): a theory describing the relationship between space and time neglecting gravity. **SR** explains how the time intervals, lengths, and mass measured by one observer relate to those measured by a second observer when in motion with respect to one another.

Synodic month, also referred to as **Lunar day (synodic):** the rotation period of the Moon, about its axis, with respect to the Sun. On average, it is approximately 29.53 solar days. This is approximately the time from local noon to local noon, on the Moon. It is also the time from full Moon to full Moon on Earth.

Terminator: the boundary between the illuminated and dark areas of an artificial or *celestial body*.

Terrestrial Time (TT): a time scale based on the *SI second* on the Earth's *geoid*, first defined by the IAU in 1991.

Three-body problem: the mathematical description of the interaction of three massive *celestial objects* modeled as point particles. Interactions with all other objects are ignored.

Time distribution: the process of distributing time from a reference clock to clocks located at other sites.

Time jamming: deliberate interference with a timing system by presence of an external signal, typically at the same or nearby frequency.

Time scale: a standardized time-measuring method, i.e., a specification comprising (a) a specific periodic natural phenomenon to be used, (b) the rate of advance (how many time units correspond to the natural period – or, vice versa, how many natural periods correspond to a time unit), and (c) an initial *epoch* (the time reading at some identifiable event).

Time slow and hold: a method to continuously adjust an onboard clock's frequency or phase by slowly modifying its rate and stabilizing the result, all while preserving the continuity of ongoing functions tied to the clock. To avoid interruptions of the functions, the tuning must be sufficiently gradual to fall within the tolerance of the system's timing requirements.

Time synchronization: the act or process of coordinating and adjusting the time of independent clocks.

Time transfer: the process of transmitting appropriately defined time signals for the purpose of *time synchronization* between two (or more) clocks.

Time zone: a region observing a uniform standard time for legal, commercial, and social purposes.

Trajectory: a conic path in space followed by an object. Although often employed interchangeably with *orbit*, the term **trajectory** is a more general term (e.g. *t*he path of a bullet is a **trajectory**, not an *orbit*).

Two-body problem (**Kepler problem**): the mathematical description of the interaction of two massive *celestial objects* viewed as point particles, using the Newtonian law of gravity. Interactions with all other objects are ignored.

Two-way time-transfer (TWTT): a method of communicating time from a source to a receiver that requires signal transmission from the receiver. The time delay due to the intervening medium cancels to the degree that the two directions are identical. Corrections can be made for known asymmetries in the two paths.

Universal Time (UT1): a time scale based on Earth's rotation around its instantaneous axis, as determined from observation. **UT1** is a modern implementation of mean solar time, with UT1 = 12h approximating mean solar noon on the Greenwich meridian. **UT1** is subject to variations in Earth's rate of rotation and can be obtained from *Coordinated Universal Time (UTC)* using the quantity UT1–UTC. Daily values of UT1–UTC are distributed by the International Earth Rotation and Reference System Service (IERS).

Zenith: the extension to infinity of a plumb line from an observer's location.